have had upon it is lost, unless the effect is preserved in the seed; and it does not matter how many generations have lived under the given uniform environment, for the plant starts all over again, *de novo*, each year. Therefore, the environment must affect the annual plant in some one generation or not at all. It seems to me to be mere sophistry to say that in plants which start anew from seeds each year, the effect of environment is not felt until after a lapse of several generations, for if that were so the plant would simply take up life at the same place every year. This philosophy is equivalent to saying that characters which are acquired in any one generation are not hereditary until they have been transmitted at least once!

My contention then, is this: plants may start equal, either from seeds or asexual parts, but may end unequal; these inequalities or unlikenesses are largely the direct result of the conditions in which the plants grow; these unlikenesses may be transmitted either by seeds or buds. Or, to take a shorter phrase, congenital variations in plants may have received their initial impulse either in the preceding generation or in the sexual compact from which the plants sprung.

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A COMPARATIVE STUDY OF THE POINT OF ACUTE VISION IN THE VERTEBRATES.[1]

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In this preliminary sketch of a comparative study of the eyes of vertebrates, with special reference to the *fovea centralis* or point of acute vision, I shall first give the processes and methods of preparation which I have used and results obtained, and, second, the position of the *area centralis* as indicated by the retinal arteries. The microscopic descriptions and the relation of the position and shape of the eye and arrangement of the retinal elements to the habits of the animal will follow in a later paper.

[1] I wish to thank Dr. C. F. Hodge for valuable assistance and for his method of injecting the eye-ball, thus preserving it for complete sections. I am also very much indebted to Clark University for valuable aid and for apparatus and materials to further this study.

For microscopical purposes and best results it is necessary to obtain the eye fresh, at least not later than an hour after death, and subject it to the action of certain hardening liquids which will permeate and preserve without causing the retina to swell and become wrinkled. With some animals it is quite easy to preserve the retina without its becoming wrinkled or floated off (fishes, amphibians, reptiles, and some mammals), while with others (most mammals and birds) it is a more difficult task.

In order to prevent this folding and floating off of the retina, the eye is injected under pressure and immersed at the same time in a bath of hardening fluid. It is carried thus on up through the different percentages of alcohol and imbedded in celloidin.

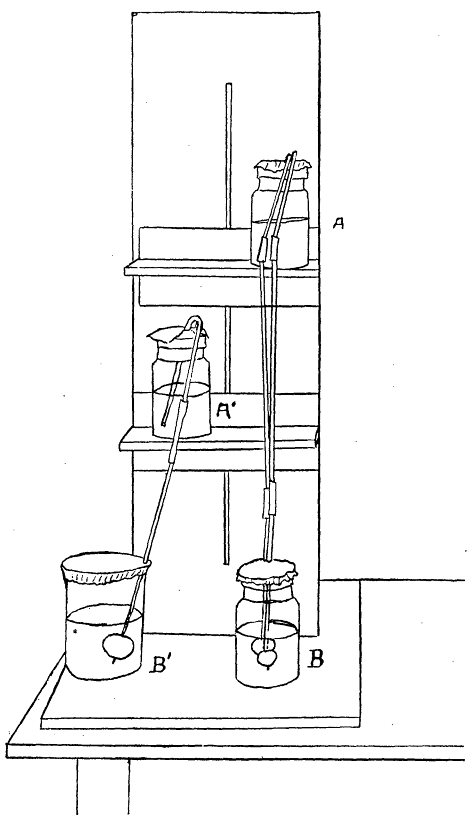

FIG. 1.

A more minute description of the method is as follows: Fig. 1 represents a rack with movable shelves, on which are placed bottles A and A′, containing the same fluid as bottles B and B′, and provided with siphons to connect with glass cannulas.

In order to insert the cannula, a hole is carefully drilled about the equator and on a meridian perpendicular to the plane in which it is desirable to obtain sections. The perforation is stretched open, rather than cut, so the sclerotic will clasp the neck of the cannula tightly. A convenient instrument for this operation is a spear-pointed dissecting needle, and not

too sharp. At the same time reach forward with the point of the needle and pierce the suspensory ligament and iris in order to open the aqueous chamber. In doing this, care is taken not to injure structures in the plane of the desired sections. A cannula of suitable size, being connected with a siphon from A or A′, is filled with the liquid and inserted. The cannula should have a fine smooth point. Great care is taken in inserting it so that the stream of fluid is not directed behind the retina to float it off. A hole is now made in the opposite side of the eye, the aqueous chamber again pierced and all aqueous and vitreous humor allowed to run out. In some animals this humor is very much more gelatinous than in others, and requires much more pressure to remove it. The hole below is then stopped with a small glass plug (Fig. 2, B), and the eye immersed in hardening fluid (Fig. 1, B). The bottles are now covered as tightly as possible with tinfoil to prevent evaporation and entrance of dust particles. The cannula and stopper should fit so tight that there is no leak. In every case the orientation of the eye is marked before it is removed from the head. This is done by sewing a small tag to the outer layers of the sclerotic (Fig. 2, C).

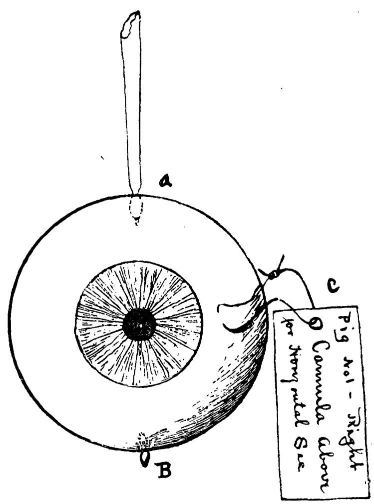

FIG. 2.

The pressure varies greatly with the kind of eye used. Those with thin walls, or containing much cartilage, birds and amphibians, require little pressure, while mammals, in general, can receive much higher. The pressures which I have found to work best vary between 28 and 36 cm.

The hardening fluid used is Perenyi's, in which the eye is allowed to remain twenty-four hours, when it is changed to 70 per cent. alcohol.

In making changes of liquids, great care should be taken that no air get into the eye, and that all the former liquid is

replaced with fresh by removing the stopper in the lower part of the eye. After remaining twenty-four hours in each of the following liquids: 80, 90, 95 per cent., absolute alcohol and absolute ether (1 part each), it is then changed to celloidin. Best results are obtained when three grades of celloidin are used—1st, very dilute; 2d, less dilute; 3d, as thick as will run. It is allowed to remain from four to six days in the first, six to eight days in the second, and ten to fifteen days in the third. If the eye is kept well under pressure throughout this process, the retina will be well preserved and lie smoothly against the choroid.

I have tried other liquids for hardening the eye whole, but with poor success. Have tried the method of Barrett and of Cuccati, but, in each case, the retina was very much wrinkled and folded, while the whole eye was much shrunken and out of shape. In vapors of osmium, I have had fairly good results with the retina, but the same trouble, due to the shrinking of the whole eye, is present. Chievitz says[2] that a fish's eye may be preserved whole, with retina lying nicely back, by simply immersing it, or even the whole head, in 80 per cent. alcohol. The hardening agent which he generally uses is 2.5 per cent. nitric acid.

Another method which I have employed with small animals, especially birds, in order to demonstrate quickly the presence or absence of a fovea, is to immerse the whole head in Perenyi's fluid for from three to five hours. This will harden the eyes so that the cornea, lens and vitreous humor may be removed, leaving the posterior half in situ. With birds I have had good results, the retina lying back smoothly so that the fovea and entrance of the nerve, marked by the pecten, may be easily seen. Fig. 3 represents diagrammatically the appearance of the retina after the front of the eye has been removed.

In order to show the angles which the lines of vision make with the median plane, sections were made through the whole head of several animals (fish, amphibians, reptiles, birds and

[2] J. H. Chievitz, Untersuchungen über die Area centralis retinae. Archiv für Anatomie und Entwickelungsgeschichte, Sup., Band, 1889, p. 141–142.

small mammals), the plane of the section passing through each fovea on the centre of the area centralis. Fig. 4 represents such a section through the foveæ *a* and *b* of a chickadee's head (*Parus atricapillus*), while the lines G H and G I show

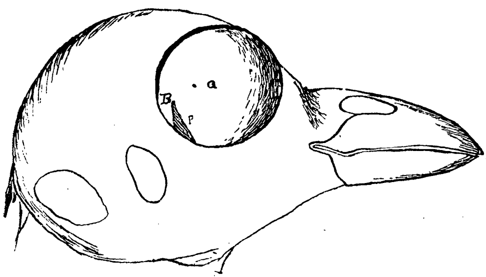

FIG. 3.

Snow-bird (*Junco hyemalis*) x 3.
A, Fovea centralis.
B, Entrance of optic nerve.
P, Pecten.

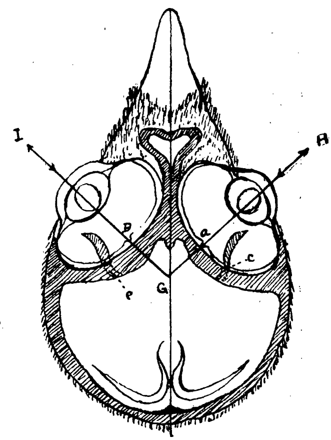

FIG. 4.

Chickadee (*Parus atricapillus*) x 3.
A and B. Foveæ.
C, C, Entrance of optic nerves.
G H and G I, Axes of vision.

the axis of vision. The dotted lines *c* mark the position of the optic nerves which enter in a plane much lower down. In order to harden the whole head, and, at the same time, decalcify the bone, it must remain longer in Perenyi's fluid (about thirty- six hours), and to preserve the cornea and lens in position, a window is made in the top of the eye that the fluids may enter.

Having had good success with simple immersion of the head, this method was tried for hardening the small eyes, and with good success. In fact, the retina proved in good condition, if not better, than when taken through by the injection method. The eye-ball, however, usually caves in when placed in 70 per cent. or 80 per cent. alcohol, but this may be prevented by simply making a small slit through the sclerotic

into the vitreous chamber before immersing in 70 per cent. alcohol to allow the liquids to pass in. Just before putting into celloidin, a window is made parallel to the plane of desired sections, and the hardened vitreous humor is easily removed without injury to the retina or other structures. This method is now used with small eyes instead of the injection, as it is so much easier of manipulation.

In order to show the relation of the retinal arteries to the area and fovea centralis, they were injected with the gelatine-carmine mass of Ranvier. In small animals this injection was made in the carotid arteries, while with large animals the eyes were removed and the injection made into that branch of the ophthalmic artery which supplies the retina. After injection, the eyes were at once cooled and hardened in alcohol. When hardened, the front half of the globe and the vitreous humor were carefully removed, exposing to view the retina, arteries, entrance of nerve, and area and fovea centralis, when present. The fovea is at once seen if it be present, but the area is sometimes very difficult to discern, and, were it not for the blood-vessels acting as land-marks, it might be overlooked altogether. Drawings were made of this posterior half, great care being taken to orient it, so that one would look into it along the axis of vision.

The results of these injections only serve to substantiate Müller's observation.[3] He states that mammals are the only class of vertebrates which possess, in the true sense, a retinal circulation, while with many mammals only a meagre circulation is present (horse and rabbit). Fish and amphibians possess a good circulation in the hyaloid membrane, while birds and many reptiles have the circulation of the pecten. Huschke states that these vessels of the hyaloid membrane and the pecten correspond to the retinal vessels in mammals. They do not, however, penetrate the retina.

With animals which have neither retinal nor hyaloid vessels, it would appear that the retina is nourished by the choroidal vessels. In fact, in animals with good retinal circulation, the capillaries do not penetrate deeper than the outer

[3] H. Müller, Anatomie und Physiologie des Auges, p. 117.

molecular layer, thus leaving the rod and cone, and outer nuclear layers without blood-vessels.[4]

Investigations show that not all vertebrates possess foveæ, but that each class has a representative which does. When there is no fovea, a well-defined area centralis is usually present. However, in some vertebrates, even an area has not been observed.

The following condensed tabulation will show the frequency of the area and fovea centralis in the eyes which have been examined.[5]

Number of different species.		No area found.	Area found.		Fovea.		
			Round.	Band-like.	Simple.	Band like or trough-like	Double.
28	Mammals	13	9	6	2		
80	Birds	1	84	32	85	23	7
9	Reptiles	1	6	2	3	2	
12	Amphibians	3	1	8	1	1	
4	Fishes	3	1		1		

From this tabulation it is readily seen, so far as experiments have gone, that in mammals the presence of a fovea is the exception while an area is the rule. The primates are the only mammals in which a fovea has been found. Most of the mammals examined have a well-defined area which is easily seen, but, in some, an area has not been demonstrated. The arrangement of the retinal vessels, however, indicates the presence of an area which is free from blood-vessels, and may correspond to the area centralis of other animals.

[4] H. Müller, Anatomie und Physiologie des Auges, p. 103.

[5] These results are partly obtained from the tabulation of J. H. Chievitz in his article: Ueber das Vorkommen der Area centralis retinae in den vier höheren Wirbelklassen. Archiv. f. Anat. u. Entwick., 1891, p. 321–325.

With birds, the presence of a fovea seems to be the rule. In fact, the domestic chicken is thus far the only exception. Many birds have a fovea and band-like area, while some have two foveæ and a band-like area connecting them.

In reptiles, the number of species provided with fovea or simple area are more nearly equal, while with amphibians and fishes, the area has frequently not been seen, and the fovea is only seldom observed.

The area centralis varies greatly in form and extent in different animals. It varies from the round form of small extent found in the cat and the weasel to the band-like form found in the horse, sheep, rabbit, frog, etc., which extends horizontally across the retina.

In the case of the fovea we also find a variety of forms and positions. In some animals it is situated on the nasal side of the entrance of the optic nerve (*fovea nasalis*), while in others it is on the temporal side (*fovea temporalis*). According to Müller,[6] in the former case we have monocular vision, while in the latter we have binocular vision. In form it varies from a mere dot-like impression, as in some lizards, to a well marked funnel-like pit in most birds, especially crow, bluejay, robin, etc., and to a trough-like depression in the crocodile which extends horizontally across the retina. Two foveæ have been found in some birds, as in swallows and terns, in which case the fovea nasalis is very near the centre of the retina, and has to do with single vision. It is also larger and deeper than the fovea temporalis, which is situated near the ora serrata and functions in double vision. According to Chievitz,[7] the tern has not only two fovæ, but a trough-like fovea connecting them, and the goose, duck and gull have a round fovea and a band-like area.

A great difference exists in the different vertebrates when their ability for acuteness of sight is considered. It varies from the most perfect sight found in man (and possibly in birds

[6] H. Müller, Ueber das Vorhandsein zweier Fovea in der Netzhaut Vieler Vogelaugen—Zehender, Klinische Monatsblätter, Sept., 1863, p. 438–440; or Anatomie und Physiologie des Auges, p. 139, 142–143.

[7] J. H. Chievitz, Ueber das Vorkommen der Area centralis retinae, Archiv. f. Anat. u. Entwick., 1891, p. 324.

also) where exceedingly fine discriminations are possible, to the limited visual power found in other animals, where only an area centralis is present. Though acute vision and a fovea have always been associated, still we cannot, at present, say that the animals which do not possess a fovea are not able to see acutely. In order to make clear the relation of sight to the habits of the animal, a much more careful observation of its visual habits, and the histological arrangement of the retinal elements will be necessary.

EDITOR'S TABLE.

—THE Antivivisectionists have been endeavoring to get a consensus of opinion on the utility of vivisection, by circulating blanks for signatures, which are attached to a few alternative opinions on the subject in point. The alternatives, excepting those expressing an unconditional affirmative and negative, were not sufficiently precise or well stated to satisfy persons of moderate views, so that it was necessary to amend them more or less to express such opinions. In the summary of the results thus obtained, the antivivisection managers omitted most of these moderate views, and only gave to the public the two extremes. The circulars were also very injudiciously distributed, as a majority of them went to persons unfamiliar with the work of scientific research, as clergymen, etc. The only persons who have a practical knowledge of the subject are original investigators in the natural sciences, physiologists and physicians. The opinions of other persons must be mostly formed at second hand.

As a body of men, those above referred to are at least as humane as any other class in the community. Their business is to relieve suffering, and they are not insensible to those of the lower animals. Naturalists, as a body, are probably more humane in their feelings towards animals than any other class in the community. Nearly all of these men are, however, well convinced not only of the propriety, but of the necessity of vivisection. It is the only method of attacking many difficult problems of physiology. It is the basis of our knowledge of the functions of the human organism, which is itself the first essential to the control of human disease and human suffering. The antivivi-